Sustainable Structures and Materials, *Vol. 6, No. 2, (2023) 23-31*
DOI: https://doi.org/10.26392/SSM.2023.06.02.023

Review of Sustainable Concrete: Building a Waste-Free and Sustainable Future

Muhammad Haseeb*[1], Mehran Sudheer[1]

[1]Capital University of Science and Technology, Islamabad, Pakistan,
**Corresponding author/ E-mail: haseeb3646@gmail.com*

(Received April 19, 2023, Revised April 28, 2023, Accepted June 5, 2023)

ABSTRACT. *Although concrete is one of the most beneficial material for the mankind yet it is one of the most unsustainable material as well. Concrete production is majorly dependent on the utilization of natural resources and is depleting the environment at an alarming rate. In order to protect the depletion of our environment, we need to introduce modern tools, sustainable materials, and processes to produce sustainable concrete. Moreover, instead of using fresh water for concrete production that could otherwise be used as drinking water, we could use alternative sources of water such as wastewater or seawater. In this review paper readers will get to know about different techniques which will help to build a waste free and sustainable environment hence reducing the environmental impact of concrete. We can use different sources of wastes to reduce the amount of binder and aggregates used for concrete production hence reducing the environmental impact of binder, coarse aggregates, and fine aggregates. Different waste materials from industrial, agricultural and domestic sources are reviewed which will help in production of sustainable concrete.*

Keywords: Sustainable Materials, Modern tools, Concrete Production Methods, Fresh Water, Environmental Impact

1. INTRODUCTION

United Nations Brundtland Commission defined sustainability as “meeting the needs of the present without compromising the ability of future generations to meet their own needs.” The sustainability of concrete is very vital for the flourishment of our planet and human beings [1]. Concrete is a mixture of cement, fine aggregates, and coarse aggregates, and their extraction and manufacturing process is greatly dependent on natural resources and is depleting them intensively. Concrete consists of 80-85% aggregates by mass and globally we are consuming approximately 15 to 16 billion tons of crushed stone every year for the production of concrete [2].

Ordinary Portland cement is not considered to be a sustainable material as it evolves to depletion of natural resources and emission of toxic and greenhouse gases. According to recent studies production of cement is responsible for 5- 10 % of emissions of carbon dioxide worldwide and this trend is moving upward due to insufficient steps taken to produce sustainable cement [3]. Cement is made using limestone, iron ore, silica, and chalk as major raw materials which is causing the depletion of natural resources and the creation of an unsustainable environment. According to studies 1.7 tons of raw materials and 4GJ of energy are required for the manufacturing of 1 ton of cement [4].

Sand is mostly used in the construction industry as a fine aggregate for infrastructure development. Sand is usually mined from river beds which is causing many harmful impacts on the ecological system of water bodies. According to surveys conducted world will run out of sand that could be mined from river beds by 2050 [5]. Keeping these facts in mind there is a dire need to find sustainable alternatives to sand and use it sustainably so our future generations could also use sand deposits to full fill their demands of sand for several purposes. Sustainable sources of sand include crushed rock sand, recycled concrete, recycled bricks, recycled glass, and industrial by-products such as copper slag and ground granulated ballast furnace slag [6].

Coarse aggregates are widely utilized in the field of the construction industry for several purposes especially the preparation of concrete. Annually 60 million tons of coarse aggregates are derived from natural resources in the UK [7]. Extraction of virgin aggregates from natural resources is highly damaging to the environment in several ways such as depletion of non-renewable resources of natural aggregates and high energy consumption in extraction and crushing processes. The use of recycled coarse aggregates from demolished construction works is a more sustainable and energy-efficient method for fulfilling our demand for coarse aggregates [8]. Sustainable resources of coarse aggregates include recycled waste from waste concrete, using ceramics waste as aggregate, and waste of brick masonry.

Concrete is one of the most widely used materials in the world. Concrete is a mixture of cement, sand, and aggregates, the extraction of which is dependent on extraction from natural resources. Due to the extraction of these materials at a very high rate our environment and natural resources are depleting at an alarming rate. To overcome this issue we can make use of waste material including industrial, agricultural, and domestic waste to reduce the burden on natural resources. Moreover, there is a dire need to introduce modern techniques to produce sustainable concrete. The use of alternative fuels 3-d concrete printing could also prove to be quite fruitful for sustainably producing concrete. To the best of author's knowledge, no research has been conducted in the past in a systematic manner on reduction of environmental impacts of concrete. The purpose of this study is to compile information regarding the concept of sustainable concrete and motivate readers to adopt sustainable construction practices.

2. REDUCE THE ENVIRONMENTAL IMPACT OF BINDER

To produce sustainable concrete we need to move towards the use of waste materials as binding agents and seek for alternative fuels to generate energy for the cement manufacturing process. Moreover, we can also use different energy-efficient methods method for clinker production [9]. Currently, limestone is majorly used in cement production and many geographical regions are running out of limestone resources for cement production [1]. The emission of greenhouse gases and depletion of natural resources due to the production of cement could be reduced by partial replacement of cement with other environmentally friendly waste materials such as industrial, agricultural, and municipal wastes. It has been proved that using supplementary cementitious materials (SCMs) up to a certain percentage can significantly minimize the negative environmental effects of the cement industry and the depletion of natural resources that could otherwise be used as virgin raw materials for the production of cement [1].

2.1. Municipal Wastes

2.1.1 Glass Powder Waste

A report found that 27 million tonnes of glass garbage were produced. Glass waste is disposed of at landfill sites and as it is a non-biodegradable material so it proves to be unsustainable for the environment [10]. The utilization of glass waste as cement replacement will prove to reduce emissions of greenhouse gases, diversion of non-recycled waste from landfills to useful applications, energy efficient and economical [11]. Glass is primarily made up of silica which proves to be an essential element in cement to give cement its binding properties [12]. The compressive strength of concrete is boosted by approximately 9% when discarded glass powder is utilized to replace up to 10% of the cement content [13]. Initially, up to 56 days, the compressive strength of concrete having glass waste powder as a replacement for cement had achieved more compressive strength however after 90 days this trend started to change. Concrete with 10% waste glass replacement in the cement showed greater compressive strength after 90 days. Concrete samples having 20% waste glass powder as a replacement for conventional binder had greater strength after 180 days. The 20% replacement of waste glass powder with cement produced 10% and 14% greater strengths at 180 and 365 days, respectively than control concrete [10].

2.2. Agricultural Waste

2.2.2 Rice Husk Ash

Rice husk is produced as a by-product of rice milling process. Around 22% of the grain's total weight is made up of rice husk during the milling process. Rice husk is used in the rice industry to burn it and use it as an alternate fuel source. The Food and Agriculture Organization of the United Nations estimated 756.7 million tons of annual paddy production in 2017 which means that approximately 166.4 million tons of rice husk could be used as an alternate and sustainable energy source in rice mills and result in the production of approximately 41.6 million tons of rice husk ash and that could be used in the production of sustainable cement [14]. Rice husk ash contains high silica content and pozzolanic [15]. Silica plays a vital role in providing its binding properties. According to the study, using 25% RHA in place of cement potentially generates concrete with the same compressive strength as that made with 100% OPC [4]. Studies show the compressive strength of concrete having different percentages of RHA as cement replacement. As the percentage of RHA increases the compressive strength of concrete decreases. The compressive strength of concrete decreases as the percentage of RHA increases above 25%. When 25% cement was replaced with RHA it showed optimum results. Rice husks have a greater tendency to absorb water so water to cement ratio of concrete having RHA is increased.

2.3. Industrial Waste

2.3.1 Granulated Ballast Furnace Slag

Granulated ballast furnace slag (GBFS) is produced as a waste material in the ferrous industry. Lime and iron ore are fed into the ballast furnace while coke is added as fuel during the manufacturing of iron and steel. The iron ore is transformed into molten iron as a result of the coke's combustion into carbon monoxide [16]. During this process, slag is produced as a waste material. Several different types of slags are produced as a result of the production of different types of metal ores. The compressive strength of concrete with 0% replacement level and 0.45 w/c ratio was 36.2MPa after 28 days; however, when 20%, 40%, and 60% GBS are used, the strength increases to 39.153MPa, 41.076MPa, and 43.6 MPa, respectively, representing increases of 7.5%, 12.78%, and 19.71% above the control concrete mix.

3. REDUCE THE ENVIRONMENTAL IMPACTS OF FINE AGGREGATE

River sand is typically utilized as fine aggregate in building projects, however, due to the construction boom, excessive sand extraction from river beds is having negative effects on the ecology [6]. Sand that covers the solid riverbed can host a wide range of germs. When sand is removed, the environment becomes unstable, and these creatures lose their home [17]. According to assessments, sand that can be mined from riverbeds and other aquatic habitats will run out worldwide by the year 2050[5]. Sand is considered to be the second most used construction material and it is estimated that roughly round 200 tons of sand is used for constructing a house and 30 tons of sand is required for the construction of every kilometre of the highway [18]. Keeping these facts in mind there is a dire need to find sustainable alternatives to sand so we could fulfil our demand for fine aggregates while bearing in mind the necessities of future generations. Alternative and sustainable sources of sand include crushed rock sand, recycled concrete, recycled bricks, recycled glass, and by-products obtained from different industrial processes such as copper slag, steel slag, and ground granulated ballast furnace slag [6].

3.1 Municipal Waste

3.1.1 Recycled Glass Fine Aggregate

Using recycled fine aggregates as a replacement to traditional aggregates prove to be quiet fruitful attempt in moving towards production of sustainable [19]. Due to low water permeability and smooth surface, grounded glass waste could enhance the properties of fresh concrete [20]. Crushing of glass is done in three stages using different machines that are imploder, shearing unit, and sanding unit. The mentioned equipment is shown in figure 1. Imploder have several blades that crush the glass. The crushed glass is then transferred to the shearing unit where further crushing takes place by shearing. After this working of the sanding unit takes place which has a circular shaft that converts the glass particles to fine aggregates. Fine particles from sanding unit are used as recycled glass fine aggregates. The mechanical properties of concrete are compromised with the introduction of recycled glass fine aggregates as a replacement for conventional aggregates.

Fig-1: Glass crushing machine (a) Imploder (b) Shearing unit and (c) Grinding shaft [21]

Table-1: Properties of fresh concrete with waste glass sand at different volume replacement levels

Volume replaced (%)	Initial Slump (mm)	Wet Density(kg/m^3)	Observations
0	40	2914	Bleeding and segregation
25	85	2941	Bleeding and segregation
50	120	2967	Homogenous but less consistent
70	135	2992	Consistent and homogenous

We can see the outcome of adding discarded glass sand to concrete from table 1. Without waste glass sand concrete showed segregation and bleeding. Moreover, it was also less workable. Experimental analysis conducted by Zhao shows that as the percentage of RHA increases the wet density of concrete increases. With the increase in percentage of the waste glass sand, the slump of concrete also increases. However, the introduction of RHA decreases the compressive strength of concrete.

3.2 Industrial Waste

3.2.1 Granulated Ballast Furnace Slag As Replacement To Fine Aggregates

Slag is a non-metallic, inert waste mostly made of silicates, aluminium silicates, and calcium-alumina-silicates. Strong water jets quickly cool molten blast furnace slag. Rapid cooling causes the molten slag to transform into granulated blast furnace slag, which is a fine, granular, and glassy form [22]. The compressive strength of concrete having GBFS as fine aggregates up to a certain percentage showed more compressive strength as compared to conventional concrete. It was shown by the studies that, up to a certain proportion, GBFS content enhances the compressive strength of concrete before it starts to decline. The highest strength was noted with 50% replacement of natural sand, and it was 35.62 MPa and 40.63 MPa after 28 days and 90 days, respectively. The concrete having GBFS as fine aggregates showed more compressive strength as compared to concrete having sand because of the pozzolanic reactivity of GBFS. During different studies, it was found that the workability of concrete having GBFS as fine aggregates showed less workability. This was majorly due to the high water absorption capacity of GBFS [22]. Various GBS percentages were tested for their effects on the effects of high temperatures, resistance to freezing and thawing, capillarity, drying-wetting effects, and sulphate resistance of concrete. It was discovered that concrete containing GBS had superior durability to standard concrete without GBS [23].

3.3 Agricultural Waste

3.3.1 Sugarcane Bagasse Ash

Bagasse is a fibrous substance consisting cellulose as primary constituent and is a raw material obtained from sugarcane. It is made in huge quantities all around the world. It is a particular kind of waste material generated by the sugar industry. Sugar industries use bagasse as an alternative source of fuel. Every year, approximately 70 sugar factories in Pakistan produce about 14 million tonnes of bagasse, which is primarily burned and only used as a landfill or a source of 3% ash for energy [24]. According to research and experimental findings, the workability of concrete rises as the SCBA percentage rises. After 7 and 28 days, respectively, the 10% SCBA utilized as fine substitute material in concrete increased the compressive strength by 4.20 and 7.90. On 7 and 28 days, the lowest value of compressive strength in concrete was reduced by 30.4% and 25% at 40% SCBA as a fine alternative [25]. According to another investigation, the compressive strength of concrete with 10% SCBA was 12.19 N/mm [26].

4. REDUCE THE ENVIRONMENTAL IMPACT OF COARSE AGGREGATES

In the construction sector, coarse aggregates are often utilized, mostly to prepare concrete. The major source used to obtain coarse aggregates are natural resources and these natural resources are non-renewable. The ecosystem is severely harmed when virgin aggregates are removed from natural resources in several ways such as depletion of non-renewable resources of natural aggregates and high energy consumption in extraction and crushing processes. The utilization of recycled coarse aggregates from destroyed building sites is a more environmentally friendly and energy-efficient way of meeting our demand for coarse aggregates [8]. Moreover, the waste generated from construction sites is itself a major problem and occupies a huge area in form of landfill sites. Statistics show that 10–30% of the waste dumped in landfills across the world is usually made up of construction and demolition waste [27]. We can manage this waste in a better manner by utilizing the construction waste for the production of sustainable concrete. Sustainable concrete could be produced from recycled coarse aggregates from demolished construction works is a more sustainable and energy-efficient method for fulfilling our demand for coarse aggregates [8].

4.1 Demolition Waste

4.1.1 Waste Brick Masonry Aggregates

Waste from brick masonry could be utilized in the production of sustainable concrete which will be economical as compared to concrete obtained from natural resources and will help in waste management. Finding new applications for demolition trash is more crucial than ever as landfill space is becoming scarce and dumping rates rise [28]. Tests performed on ordinary Portland concrete with recycled brick masonry aggregates showed satisfactory results even with 100% replacement with conventional unsustainable natural aggregates [29].

According to experiment findings, recycled brick masonry aggregates (RBMA) have a unit weight that is much lower than that of traditional, non-sustainable aggregates made from depleted natural resources. However, the unit weight of RBMA is a bit more than the maximum weight for lightweight aggregates as specified in ASTM C330 [29]. According to another resource also the loose bulk density of recycled brick masonry aggregates was found to be less than that of conventional aggregates obtained from the depletion of natural resources [28]. The compressive strength of concrete containing RBMA was measured to be 5,440 psi, which is close to the compressive strength of standard Portland cement concrete with typical aggregates.

4.2 Industrial Aggregates

4.2.1 Waste Ceramic Aggregates

Ceramics is a widely produced product in the world. It is also highly durable so it is exported to other countries of the world without major fear of damaging the products [30]. Although the use of discarded ceramic waste as coarse aggregates in concrete is a sustainable solution, their separation from the mortar is expensive, and the mortar offers no advantage for use in concrete. As a result, the sole alternative for usage in concrete remains shattered pure ceramic tiles [31]. Studies have shown enhancement in the properties of concrete in the introduction of waste ceramic aggregates. The compressive strength of concrete was raised by 9% when natural aggregates were substituted with waste ceramic aggregates by up to 9% [32]. Another study discovered that by completely replacing discarded ceramic aggregates with conventional aggregates derived from natural resources, the compressive strength of concrete rose by 14% [33]. On contrary, another study even reported a decrease of 34% in the compressive strength of concrete when prepared by replacing 100% natural coarse aggregates with waste ceramic aggregates [34]. This may be due to different types of ceramics used as a replacement to unsustainable coarse aggregates [35]. In general, replacing red ceramic wastes with natural aggregates has been proven to have a negative influence on concrete durability measures such as compressive strength [36]. According to research, the density of waste ceramic aggregates is lower than that of ordinary aggregates. As a result, the density of concrete made from waste ceramic particles will be lowered. Hence the overall weight of the building could be reduced by using sustainable and economical aggregates as well as the reinforcement required to make the building earthquake-resistant will also be reduced which means that less steel reinforcement would be required. Waste ceramic aggregates' ability to interlock with ease when pressed is primarily due to their form and moisture content, which is the main factor in their increased strength. Waste ceramic aggregates' ability to interlock with ease when pressed is primarily due to their form and moisture content, which is the main factor in their increased strength [35].

4.3 Agricultural Waste

4.3.1 Coconut Shell Waste

Conventional aggregates are readily available at economical prices however mining of aggregates from natural resources is depleting the environment to a great extent. Therefore finding materials that can be utilized as a substitute to coarse aggregate in concrete is becoming more and more necessary [37]. Coconut is widely produced and used all around the world and its waste is an environmental threat. In order to cater this problem and reduce environmental impact of concrete we can use coconut sell waste as a substitute to natural aggregates. Studies show that coconut shell aggregates compared to typical aggregates show greater resistance to crushing, impact, and abrasion [38]. According to studies, the compressive strength of concrete falls as the proportion of coconut shell aggregates rises, whereas the flexural strength of concrete increases when the proportion of CSW rises over 35%. Concrete with 100% conventional aggregates had a compressive strength of 28.3 MPa after 28 days of curing, but concrete with 10% and 20% CSW had compressive strengths of 25.6 MPa and 25.3 MPa, respectively [39]. After 28 days of curing, concrete with 100% conventional aggregates had a flexure strength of 3.17 MPa, whereas concrete with 10% and 20% CSW had values of 2.01 MPa and 2.6 MPa, respectively [37].

5. USE OF NON-CONVENTIONAL SOURCES OF WATER

A well-known global issue relating to water supplies and human demand is the "water crisis." In many countries around the world, this issue has an impact on food, agriculture, and health. To overcome this issue there is a dire need to reuse water in industries that consume large quantities of water such as ready-mix concrete plants [40]. It may be more ecologically beneficial to use non-water resources instead, such as the seas, desalination water, treated or untreated effluent discharged, saline water, brackish water, poor quality groundwater, agricultural drainage water and return flows, rainwater, storm water, greywater, and other water resources containing hazardous components and sediments [41]. It will result in higher quality water being reserved for important needs like drinking while using lower quality water for other uses [42]. Studies show that proper testing should be done before using wastewater in concrete manufacturing processes and strict monitoring is also required. Moreover, waste water decreases the compressive strength of concrete if no additives are used. However, research indicates that the bulk of the sludge powder is a calcareous fine material that could not degrade the characteristics of concrete; rather, it may improve compressive strength when utilized suspended in the mixing water, filling in for limestone and raising packing index. If we want to use waste water in concrete we should first treat the water accordingly and bring all parameters of water quality by ASTM standards [40].

6. METHODS TO PRODUCE SUSTAINABLE CONCRETE

Concrete could be produced in a much more sustainable manner using non-conventional and modern techniques. Sustainability in concrete production could be achieved through different methods such as using alternative fuel sources, increasing the efficiency of machinery, and, printing 3-D concrete. The objective of adopting modern concrete production techniques is to reduce the carbon footprint and environmental impact of concrete production.

6.1 Use Of Refuse-Derived Fuel In Cement Industry

The term RDF stands for refuse-derived fuel. In the modern world, solid waste management is a major issue and landfills are not only occupying a large area of the earth but also a severe number of greenhouse gases including methane[43]. Moreover, the cement industry requires a large amount of fossil fuels for cement production processes. Bringing these two issues together scientists discover use of RDF in the cement industry [44].

RDF is type of alternative fuel made from recyclable materials such as plastics found in municipal or industrial solid waste or from materials that are difficult to recycle after decomposition. When non-combustible materials like ferrous metal, glass, grit, and other non-combustible materials are removed, what is left over is often pelletized or fluffy MSW. The residual substance is then known as RDF and utilized as a secondary fuel in the manufacturing of clinker [45].

Due to the special characteristics of cement kilns, which have flame temperatures that burn at or above 2000 °C, RDF and similar materials may be completely degraded without producing waste ash or hazardous pollutants. In addition, because burning produces energy that may be recovered, it makes efficient use of a material that would otherwise be wasted. In this way, the burden from natural resources of fuel could also be reduced in addition to the burden on landfill sites. When the cement industry uses alternative fuels and uses RDF as an energy source, the greenhouse gases released by the decomposition and burning of waste materials in landfills and incineration plants will be less. Depending on the kind of waste and the method of disposal, these indirect emissions reductions may be greater, less, or equal to the direct CO_2 emissions from alternative fuel burning at the cement plant. The use of alternative fuels in place of traditional fossil fuels is a useful strategy for cutting global GHG emissions because of the effects that these fuels have on direct emissions, indirect emission reduction, and resource efficiency [46].

6.2 3-D Concrete Printing

Concrete is the most widely produced construction material and its production is increasing continuously. During construction, the actual cost of concrete itself is only 40 to 65% percent and the rest of the cost is related to formwork which may be made up of timber or steel and acts like a mould for concrete [47]. According to a study conducted 80% of construction waste generated belongs to discarded formwork which is of little to no value [48] To deal with these issues, the concept of 3-D concrete printing has emerged. Moreover, with 3-D concrete printing, the creativity of architects is not bound to certain shapes of formwork or paying for additional costs to get bespoke formwork. The first effective researcher to explore the use of additive manufacturing in construction was Pegna [49]. The method adopted was making constructions out of the sand and then sticking them together with cement. In comparison to traditional building methods, the use of 3D printing technology in concrete construction may offer outstanding advantages like:

- A decrease in construction expenses due to the removal of formwork.
- A decrease in injury rates through the elimination of hazardous jobs (such as working at heights), would lead to an improvement in construction safety.
- The development of high-end, technological jobs.
- Shortening the duration of the building process on-site by proceeding steadily.
- Losses can be avoided by carefully positioning material.
- Improving sustainability in construction by lowering formwork waste.
- Due to no need for formwork architects are free to construct more complex structural and architectural designs [50].

7. CONCLUSION

This study is conducted to gather information regarding strategies that could be adopted to produce sustainable concrete so the environmental impact of concrete manufacturing could be reduced. Moreover, this study aimed to reduce solid waste management issues by using waste material in concrete as a replacement for conventional materials which are extracted from nature.

- Reduce the Environmental Impacts of Binder:

Cement is a binder material and a vital constituent of concrete having adverse environmental impacts. The extraction of raw materials from natural resources is necessary for the manufacturing of cement but these resources are being depleted at an alarming rate because of the high extraction rate. The environmental impact of binder could be reduced by decreasing the amount of binder used in concrete by replacing cement with other non-conventional materials. These materials could be reused from waste generated by different walks of life. The source of these non-conventional materials could be industrial, agricultural, and municipal waste.

- Reduce the Environmental Impacts of Aggregates:

These aggregates are obtained from natural resources such as rivers, oceans, and mountains. According to different studies conducted, although the use of aggregates is 12 times higher as compared to the use of binder its environmental impact is negligible as compared to that of cement. However, the EI of aggregate production is still increasing at a startling rate. This research demonstrates the wide range of potential sources for aggregates to be used in concrete from different sources of wastes. The majority of the time, aggregate composition and properties have little impact on how long concrete will last.

- Methods to Produce Sustainable Concrete:

To move a step forward toward sustainable concrete we need to explore more methods to produce sustainable concrete. Several studies are conducted to reduce the adverse environmental impact of concrete production and extraction of materials that are used for concrete production however most of the studies are focusing on a single aspect while ignoring many others for example economy, durability, or environmental impact. Many studies have been conducted over time so the environmental impact of concrete could be reduced using modern techniques such as 3-D concrete printing and use of RDF however these techniques reduce the properties of concrete in one way or the other.

8. RECOMMENDATIONS

Concrete production is very adversely impacting the environment and there is a dire need to address environmental impacts of concrete. There is a need for intensive working to be done in order to produce sustainable concrete. It is very necessary to conduct awareness campaigns on environmental impacts of concrete. Moreover, governments in all countries around the globe should praise those using sustainable concrete and offer incentives for buildings constructed using sustainable concrete especially in terms of taxes.

REFERENCES

[1] Naik, T.R., *Sustainability of concrete construction.* Practice Periodical on Structural Design and Construction, 2008: p. 13(2), 98-103.
[2] Mehta, K.P., *Reducing the environmental impact of concret.* Concrete international, 23(10), 2001: p. 61-66.
[3] Kahhata, R., et al., *Production of cement in Peru: Understanding carbon-related environmental impacts and their policy implications.* Resources, Conservation and Recycling, 2019: p. 283-292.
[4] Khan, R., Jabbar, A., Ahmad, I., Khan, W., Khan, A. N., & Mirza, J., *Reduction in environmental problems using rice-husk ash in concrete.* Construction and Building Materials, 30, 2012: p. 360-365.
[5] Rentier, E.E., & Cammeraat, L. E., *The environmental impacts of river sand mining.* Science of The Total Environment,, 2022: p. 155877.
[6] Kirthika, S.K., Singh, S. K., & Chourasia, A., *Alternative fine aggregates in production of sustainable concrete-A review.* Journal of cleaner production, 268, 2020: p. 89-122.
[7] Damdelen, O., *Investigation of 30% recycled coarse aggregate content in sustainable concrete mixes.* Construction and Building Materials, 184, 2018: p. 408-418.
[8] Limbachiya, M., Meddah, M. S., & Ouchagour, Y, *Use of recycled concrete aggregate in fly-ash concrete* Construction and Building Materials, 27(1), 2012: p. 439-449.
[9] Schneider, M., Romer, M., Tschudin, M., & Bolio, H, *Sustainable cement production—present and future.* Cement and concrete research, 41(7), , 2011: p. 642-650.
[10] Islam, G.S., Rahman, M., & Kazi, N., *Waste glass powder as partial replacement of cement for sustainable concrete practice.* International Journal of Sustainable Built Environment, 6(1), 2017: p. 37-44.
[11] Matos, A.M., & Sousa-Coutinho, J., *Durability of mortar using waste glass powder as cement replacement.* Construction and building materials, 36, 2012: p. 205-215.
[12] Shelby, J.E., *introduction to glass science and technology*. 2020: Royal society of chemistry.
[13] Aliabdo, A.A., Abd Elmoaty, M., & Aboshama, A. Y., *Utilization of waste glass powder in the production of cement and concrete.* Construction and Building Materials, 124, 2016: p. 866-877.
[14] Nations, F.a.A.O.o.U., *FAO Rice Market Monitor Volume XX*. 2017: Italy.
[15] Alex, J., Dhanalakshmi, J., & Ambedkar, B., *Experimental investigation on rice husk ash as cement replacement on concrete production.* Construction and Building Materials, 127, 2016: p. 353-362.
[16] Preetham, H.K., & Nayak, S, *Geotechnical investigations on marine clay stabilized using granulated blast furnace slag and cement.* International Journal of Geosynthetics and Ground Engineering, 5(4), 2019: p. 1-12.
[17] Zou, W., Tolonen, K. T., Zhu, G., Qin, B., Zhang, Y., Cao, Z., ... & Gong, Z., *Catastrophic effects of sand mining on macroinvertebrates in a large shallow lake with implications for management.* Science of the Total Environment, 695, 2019: p. 133706.

[18] Ludacer, R., *The world is running out of sand— and there's a black market for it now.* 2018, Business Insider Nederland.
[19] Tamanna, N., Tuladhar, R., & Sivakugan, N., *Performance of recycled waste glass sand as partial replacement of sand in concrete.* Construction and Building Materials, 239, 2020: p. 117804.
[20] Zhao, H., Poon, C. S., & Ling, T. C., *Utilizing recycled cathode ray tube funnel glass sand as river sand replacement in the high-density concrete.* Journal of cleaner production, 51, , 2013: p. 184-190.
[21] Tamanna, N., Tuladhar, R., & Sivakugan, N, *Performance of recycled waste glass sand as partial replacement of sand in concrete.* Construction and Building Materials, 239, 2020.
[22] Patra, R.K., & Mukharjee, B. B, *Influence of incorporation of granulated blast furnace slag as replacement of fine aggregate on properties of concrete.* Journal of cleaner production, 165, 2017: p. 468-476.
[23] Yüksel, İ., Bilir, T., & Özkan, Ö, *Durability of concrete incorporating non-ground blast furnace slag and bottom ash as fine aggregate.* Building and Environment, 42(7), 2007: p. 2651-2659.
[24] Mangi, S.A., Jamaluddin, N., Ibrahim, M. W., Awal, A. A., Sohu, S., & Ali, N. *Utilization of sugarcane bagasse ash in concrete as partial replacement of cemen*. in *IOP conference series: materials science and engineering*. 2017. IOP Publishing.
[25] Dayo, A.A., Kumar, A., Raja, A., Bheel, N., & Shaikh, Z. H., *Use of sugarcane bagasse ash as a fine aggregate in cement concrete.* Engineering Science and Technology International Research Journal, 2019: p. 8-11.
[26] Modani, P.O., & Vyawahare, M. R. *Utilization of bagasse ash as a partial replacement of fine aggregate in concrete*. in *Procedia Engineering*. 2013. Elsevier.
[27] Begum, R.A., Siwar, C., Pereira, J. J., & Jaafar, A. H., *A benefit–cost analysis on the economic feasibility of construction waste minimisation: The case of Malaysia.* Resources, conservation and recycling, 48(1), 2006: p. 86-98.
[28] Cavalline, T.L., *Recycled brick masonry aggregate concrete: Use of recycled aggregates from demolished brick masonry construction in structural and pavement grade portland cement concrete*. 2012, The University of North Carolina at Charlotte: Chappel Hill.
[29] Schwerin, D.E., Cavalline, T. L., & Weggel, D. C, *Use of recycled brick masonry aggregate and recycled brick masonry aggregate concrete in sustainable construction.* Journal of Construction Engineering and Project Management, 3(1), 2013: p. 28-34.
[30] Rashid, K., Razzaq, A., Ahmad, M., Rashid, T., & Tariq, S, *Experimental and analytical selection of sustainable recycled concrete with ceramic waste aggregate.* Construction and Building Materials, 154, 2017: p. 829-840.
[31] Tabak, Y., Kara, M., Günay, E., Yildirim, S. T., & Yilmaz, Ş.. . In, Chania. *Ceramic tile waste as a waste management solution for concrete*. in *3rd International Conference on Industrial and Hazardous Waste Management*. 2012. Crete.
[32] Guerra, I., Vivar, I., Llamas, B., Juan, A., & Moran, J., *The effects of using recycled ceramic material from sanitary installations on the mechanical properties of concrete.* Waste management, 29(2), 2009: p. 643-646.
[33] Higashiyama, H., Yagishita, F., Sano, M., & Takahashi, O, *Compressive strength and resistance to chloride penetration of mortars using ceramic waste as fine aggregate.* Construction and Building Materials, 26(1), 2012: p. 96-101.
[34] Cabral, A.E.B., Schalch, V., Dal Molin, D. C. C., & Ribeiro, J. L. D, *Mechanical properties modeling of recycled aggregate concrete.* Construction and Building Materials, 24(4), 2010: p. 421-430.
[35] Keshavarz, Z., & Mostofinejad, D, *Porcelain and red ceramic wastes used as replacements for coarse aggregate in concrete.* Construction and Building Materials, 195,, 2019: p. 218-230.
[36] Correia, J.R., de Brito, J., & Pereira, A. S., *Effects on concrete durability of using recycled ceramic aggregates.* Materials and structures, 39(2), 2006: p. 169-177.
[37] Rajeevan, B., & Shamjith, K. M., *A study on the utilization of coconut shell as coarse aggregate in concrete.* International Journal of Engineering Research and Technology (IJERT), 2015: p. 77-80.
[38] Reddy, B.D., Jyothy, S. A., & Shaik, F. E. J. Mech., *xperimental analysis of the use of coconut shell as coarse aggregate.* IOSR Journal of Mechanical and Civil Engineering, 2014: p. 6-13.
[39] Kanojia, A., & Jain, S. K., *Performance of coconut shell as coarse aggregate in concrete. .* Construction and Building Materials, 140, 2017: p. 150-156.
[40] Tsimas, S., & Zervaki, M., *Reuse of waste water from ready-mixed concrete plants.* Management of Environmental Quality: An International Journa, 2011.
[41] Kaboosi, K., *Experimental and statistical studies of using the non-conventional water and zeolite to produce concrete.* European Journal of Environmental and Civil Engineering, 26(12), 2022: p. 5931-5947.
[42] Morote, Á.F., Olcina, J., & Hernández, M., *The use of non-conventional water resources as a means of adaptation to drought and climate change in Semi-Arid Regions: South-Eastern Spain.* Water, 11(1), 2019: p. 93.

[43] Paolo, M., & Paola, M., *RDF: from waste to resource–the Italian case.* Energy Procedia, 81, 2015: p. 569-584.

[44] Dong, T.T., & Lee, B. K., *Analysis of potential RDF resources from solid waste and their energy values in the largest industrial city of Korea.* Waste management, 29(5) 2009: p. 1725-1731.

[45] Kara, M., *Environmental and economic advantages associated with the use of RDF in cement kilns. Resources.* Conservation and Recycling, 68, 2012: p. 21-28.

[46] CSI, C.S.I., *CO2 accounting reporting standard for the cement industry*. 2005, The cement CO2 protocol.

[47] Johnston, D.W., *Design and construction of concrete formwork.* Concrete construction engineering handbook, 2008: p. 7-49.

[48] Lim, S., Buswell, R. A., Le, T. T., Austin, S. A., Gibb, A. G., & Thorpe, T., *Developments in construction-scale additive manufacturing processess.* Automation in construction, 21, 2012: p. 262-268.

[49] Pegna, J., *Exploratory investigation of solid freeform construction.* Automation in construction, 5(5), 1997: p. 427-437.

[50] Sanjayan, J.G., & Nematollahi, B., *3D concrete printing for construction applications. In 3D concrete printing technology*. Butterworth-Heinemann, 2019: p. 1-11.